ENCLOSURE 2

Advisory Circular

Advisory Material Joint

Subject: Control Systems- General **Date:** 19 March 2001 **AC/AMJ No:** 25.671

Initiated By: FCHWG **Change:** Post TAEIG ~~Final~~ Draft

Table of Contents:

ENCLOSURE 2

1. PURPOSE.

a. This AC/AMJ provides an acceptable means, but not the only means, of showing compliance with the control system requirements of 14 CFR 25.671 (referred to as FAR/JAR 25.671 in this AC/AMJ) of the Federal Aviation Requirements (FAR)/Joint Airworthiness Requirements (JAR). These means are intended to provide guidance to supplement the engineering and operational judgment that must form the basis of any compliance demonstration.

b. The means described in this AC/AMJ are neither mandatory nor regulatory in nature and do not constitute a regulation. These means are issued, in the interest of standardization, for guidance purposes and to outline a method that has been found acceptable in showing compliance with the standards set forth in the rule. Because this AC/AMJ is not mandatory, terms "shall" and "must" used in this AC/AMJ only apply to those applicants who choose to demonstrate compliance using this particular method.

c. Other, alternate means of compliance that an applicant may propose should be given due consideration, provided they meet the intent of the regulation. In the absence of a rational analysis substantiated by data supporting alternative criteria, the criteria listed in this AC/AMJ may be used to show compliance with FAR/JAR 25.671.

2. CANCELLATION.

The following material is cancelled by this AC/AMJ:

a. ACJ 25.671(a), Control Systems – General (Interpretive Material)

b. ACJ 25.671(b), Control Systems – General (Interpretive Material)

c. ACJ 25.671(c)(1), Control Systems – General (Interpretive Material)

ENCLOSURE 2

3. RELATED DOCUMENTS.

The following regulatory and advisory materials are related information:

a. Regulations.

(1) FAR/JAR 25.21(e), General - Proof of Compliance.

(2) FAR/JAR 25.143, Controllability and Maneuverability - General.

(3) FAR/JAR 25.302, Interaction of Systems and Structures.

(4) FAR/JAR Part 25 -- Appendix K, Interaction of Systems and Structures.

(5) FAR/JAR 25.331, Symmetric Maneuvering Conditions.

(6) FAR/JAR 25.571, Damage-Tolerance and Fatigue Evaluation of Structure.

(7) FAR/JAR 25.629, Aeroelastic Stability Requirements.

(8) FAR/JAR 25.671, Control Systems – General.

(9) FAR/JAR 25.672 (FCHWG Draft), Stability Augmentation and Automatic and Power-Operated Systems.

(10) FAR/JAR 25.683, Operation Tests.

(11) FAR/JAR 25.701, Flap and Slat Interconnection.

(12) FAR/JAR 25.1309 (SDAHWG Draft), Equipment, Systems, and Installations.

(13) FAR/JAR 25.1322, Warning, Caution, and Advisory Lights.

(14) FAR/JAR 25.1329, Automatic Pilot Systems.

(15) FAR/JAR 25.1435, Hydraulic Systems.

(16) FAR/JAR 25.1581(a)(2), Airplane Flight Manual - General.

(17) FAR/JAR 25.1583, Operating Limitations.

b. Advisory Circulars, Advisory Material Joint.

(1) AC 25-7A, Flight Test Guide for Certification of Transport Category Airplanes.

(2) AC/AMJ 25.1309 (SDAHWG Diamond Draft), System Design and Analysis.

c. Industry Documents.

(1) RTCA/DO-178B/EUROCAE ED12B, Software Considerations in Airborne Systems and Equipment Certification.

(2) SAE ARP 4754, Certification Considerations for Highly Integrated or Complex Aircraft Systems.

(3) SAE ARP 4761, Guidelines and Methods for Conducting the Safety Assessment Process on Civil Airborne Systems and Equipment.

4. APPLICABILITY OF 14 CFR 25.671 AND ADVISORY MATERIAL.

14 CFR 25.671 (referred to as FAR/JAR 25.671 in this AC/AMJ) applies to all flight control system installations (including primary, secondary, trim, lift, drag, feel, and stability augmentation systems) regardless of implementation technique (manual, powered, fly-by-wire, or other means).

5. DEFINITIONS.

The following definitions apply to the requirements of FAR/JAR 25.671 and the guidance material provided in this AC/AMJ. Unless otherwise stated, they should not be assumed to apply to the same or similar terms used in other regulations or ACs/AMJs. Terms for which standard dictionary definitions apply are not defined herein.

a. At Risk Time. The period of time during which an item must fail in order to cause the failure effect in question. This is usually associated with the final fault in a fault sequence leading to a specific failure condition. See also SAE ARP 4761.

b. Catastrophic Condition. As used in AC/AMJ 25.1309 (reference 3.b.2).

c. Continued Safe Flight and Landing. The capability for continued controlled flight and landing at an airport without requiring exceptional pilot skill or strength.

d. Dormant Failure. A dormant failure is defined as one that has already occurred, but has not become evident to the flight crew or maintenance personnel. (The advisory material to 25.1309 uses the term "latent" in this application.)

e. Dormancy Period. The duration between actions necessary to check for the existence of a failure – the action may be a pre-flight flight crew check, periodic maintenance check, or periodic maintenance inspection (including component overhaul). See also "Exposure Time."

f. Error. An omission or incorrect action by a crewmember or maintenance personnel, or a mistake in requirements, design, or implementation. See also AC/AMJ 25.1309 and SAE ARP 4761.

g. Event. An occurrence that has its origins distinct from the airplane, such as atmospheric conditions (e.g., gusts, temperature variations, icing, and lightning strikes) and runway conditions, but is not intended to cover sabotage. See also AC/AMJ 25.1309 and SAE ARP 4761.

h. Exposure Time. The period of time between when an item was last known to be operating properly and when it will be known to be operating properly again. See also SAE ARP 4761.

i. Extremely Improbable. As used in AC/AMJ 25.1309 (reference 3.b.2).

j. Extremely Remote. As used in AC/AMJ 25.1309 (reference 3.b.2).

k. Failure. An occurrence that affects the operation of a component, part, or element such that it can no longer function as intended (this includes both loss of function and operation outside specified limits). Note: Errors may cause Failures, but are not considered to be Failures. See also "failure" and "malfunction" in AC/AMJ 25.1309 and SAE ARP 4761.

The following are some of the types of failures to be considered in showing compliance with FAR/JAR 25.671(c). Since the type of failure and the failure's effect will depend on system architecture this list is not all-inclusive, but serves as a general guideline.

(1) Jam. A failure or event such that a control surface, pilot control, or component is fixed in one position.

(i) If the control surface or pilot control is fixed in position due to a physical interference, it is addressed under FAR/JAR 25.671(c)(3). Causes may include corroded bearings, interference with a foreign or loose object, control system icing, seizure of an actuator, or a disconnect that results in a jam by

creating an interference. Jams of this type must be assumed to occur and should be evaluated at positions up to and including the normally encountered positions defined in Section 9.b.

(ii) All other failures that result in a fixed control surface, pilot control, or component are addressed under FAR/JAR 25.671(c)(1), 25.671(c)(2), and 25.671(c)(4), as appropriate. Depending on system architecture and the location of the failure, some jam failures may not always result in a fixed surface or pilot control; for example, a jammed valve could result in a surface runaway.

(2) Loss of Control of Surface. A failure such that a surface does not respond to commands. Failure sources include control cable disconnection, actuator disconnection, or loss of hydraulic power. In these conditions, the position of the surface(s) or controls can be determined by analyzing the system architecture and airplane aerodynamic characteristics; common positions include surface centered (0°) or zero hinge-moment position (surface float).

(3) Oscillatory Failure. A failure that results in undue surface oscillation. Failure sources include control loop destabilization, oscillatory sensor failure, oscillatory computer or actuator electronics failure. The duration of the oscillation, its frequency, and amplitude depend on the control loop, monitors, limiters, and other system features.

(4) Restricted Control. A failure that results in the achievable surface deflection being limited. Failure sources include foreign object interference or travel limiter malfunctioning. This failure is considered under FAR/JAR 25.671(c)(1) and 25.671(c)(2), as the system/surface can still be operated.

(5) Runaway or Hardover. A failure that results in uncommanded control surface movement. Failure sources include servo valve jamming, computer or actuator electronics malfunctioning. The speed of the runaway, the duration of the runaway (permanent or transient) and the resulting surface position (full or partial deflection) depend on the available monitoring, limiters and other system features. This type of failure is specifically addressed in FAR/JAR 25.671(c)(4).

(6) Stiff or Binding Controls. A failure that results in a significant increase in control forces. Failure sources include failures of artificial feel systems, corroded bearings, jammed pulleys, and failures causing high friction. This failure is considered under FAR/JAR 25.671(c)(1) and 25.671(c)(2), as the system/surface can still be operated. In some architectures, the higher friction may result in reduced centering of the controls.

l. Failure States. As used in 25.671(c), this term refers to the sum of all failures and failure combinations contributing to a hazard, apart from the single failure being considered, and including the effect of exposure time.

m. Flight Control System. Flight control system refers to the following: primary flight controls from the pilots' controllers to the primary control surfaces, trim systems from the pilots' trim input devices to the trim surfaces (incl. stabilizer trim), speedbrake/spoiler (drag devices) systems from the pilots' control lever to the spoiler panels or other drag/lift-dumping devices, high lift systems from the pilots' controls to the high lift surfaces, feel systems, and stability augmentation systems. Supporting systems (i.e., hydraulic systems, electrical power systems, avionics, etc.) should also be included if failures in these systems have an impact on the function of the flight control system.

n. Probable. As used in AC/AMJ 25.1309 (reference 3.b.2).

o. Probability vs. Failure Rate. Failure rate is typically expressed in terms of average probability of occurrence per flight hour. In cases where the failure condition is associated with a certain flight condition that occurs only once per flight, the failure rate is typically expressed as average probability of occurrence per flight (or per takeoff, or per landing). Failure rates are usually the "root" numbers used in a fault tree analysis prior to factoring in dormancy periods, exposure time, or at risk time. Probability is non-dimensional and expresses the likelihood of encountering or being in a failed state. Probability is obtained by multiplying a failure rate by the appropriate exposure time.

p. Remote. As used in AC/AMJ 25.1309 (reference 3.b.2).

q. Single Failure Considerations. As used in AC/AMJ 25.1309 (reference 3.b.2).

6. BACKGROUND.

Two sets of requirements exist for flight control systems: FAR/JAR 25.671 and FAR/JAR 25.1309. Both are aimed at ensuring an adequate level of safety. FAR/JAR 25.1309 has the advantage of being associated with structured assessment methods and guidelines. While useful as a general guide for analysis and a complement to the requirements of FAR/JAR 25.671, FAR/JAR 25.1309 does not specifically address (1) minimum residual airplane capabilities following single failures, nor (2) the concept of control jams in normally encountered positions. FAR/JAR 25.671 specifically addresses these two areas.

This advisory material was developed to harmonize FAA and JAA requirements and provide guidance in showing compliance to FAR/JAR 25.671. This material addresses the existing JAA ACJ guidance as well as the following regulatory areas:

ENCLOSURE 2

a. FAR/JAR 25.671(c) prescribes the failure conditions that must be considered in a control system design. While the failure conditions in FAR/JAR 25.671(c) are similar to those to be considered under FAR/JAR 25.1309, there are differences between the rules that lead to confusion and inconsistent application of FAR/JAR 25.671(c). In addition, JAR 25.671(c)(1) allows the exclusion of single failures that can be shown to be extremely improbable; FAR 25.671(c)(1) requires all single failures, regardless of failure probability, to be considered. FAR 25.671(c)(1) and JAR 25.671(c)(1) need to be harmonized. A uniform means of compliance to FAR/JAR 25.671(c) needs to be developed. It is expected that considerable elaboration would be made as to how the various mechanical, hydraulic, and electrical failures should be handled. Consideration should be given to dormant failures and the relationship of the flight control failures with the occurrence of engine failures.

b. Using the rate of control jams experienced in the transport fleet to date, and in service experience as an indicator of types control system malfunctions that may be safety concerns, the following aspects of 25.671 were also addressed:

   (1) Defined the meaning of the terms "normal flight envelope", "without exceptional piloting skill or strength", "minor effects", and " position normally encountered" as used in § 25.671(c).

   (2) Determined to what extent basic skills and reasonable pilot response and action may be used to alleviate the resulting airplane control problems. Determined the applicability of crosswind to the landing situation with a jammed flight control.

   (3) Identified acceptable methodology by which judge the controllability/maneuverability of an airplane with a jammed control system (e.g. Handling Qualities Rating System --HQRM).

   (4) Reviewed & responded to NTSB Recommendation A-96-108 & A-99-23.

   (5) Considered comments in AIA-GAMA letter dated January 23, 1997 and the input received at the December 3, 1996, public meeting conducted by the FAA.

   (6) Addressed structural loading conditions following the jammed failure condition required for continued safe flight and landing.

c. Provided advisory material that addresses all engine failure condition defined in FAR/JAR 25.671(d).

d. The confusion of two different interpretations and inconsistent application of prior FAR/JAR 25.671(c)(2) was clarified with new wording and advisory material.

   One interpretation of prior FAR/JAR 25.671(c)(2) focused on "combination of failures not shown to be extremely improbable" and considered this requirement essentially

equivalent with the analysis required by AC/AMJ 25.1309. The examples in the parenthetical expression of prior FAR/JAR 25.671(c)(2) were viewed as examples only and not the main intent of the rule. Therefore, all combinations of failures that were not extremely improbable ($1x10^{-9}$/FH) were considered.

A different interpretation of prior FAR/JAR 25.671(c)(2) focused on the parenthetical expression and considered the failure combinations listed as the kinds of failures not considered to be extremely improbable, regardless numerical probability. Further, the phrase "any single failure in combination with any probable hydraulic or electrical failure" had been expanded to a more generic form of "any single failure in combination with any probable failure." Therefore, "single+probable" failures were not considered extremely improbable (regardless of probability) and therefore were to be considered for compliance.

7. EVALUATION OF CONTROL SYSTEM OPERATION – 25.671(a).

a. Control systems for essential services should be so designed that when a movement to one position has been selected, a different position can be selected without waiting for the completion of the initially selected movement, and the system should arrive at the finally selected position without further attention. The movements that follow and the time taken by the system to allow the required sequence of selection should not be such as to adversely affect the airworthiness of the airplane.

b. Compliance should be shown by evaluation of the closed loop flight control system. This evaluation is intended to ensure that there are no features or unique characteristics (including numerical singularities) which would restrict the pilot's ability to recover from any attitude. It is not the intent of this rule or guidance material to limit the use of envelope protection features or other systems that augment the control characteristics of the aircraft.

8. EVALUATION OF CONTROL SYSTEM ASSEMBLY – 25.671(b).

This rule is intended to ensure the parts applicable to the type design are correctly assembled and is not intended to address parts control (ref. 25.1301(b), 45.14, & 45.15).

a. For control systems, the design intent should be such that it is impossible to assemble elements of the system so as to prevent its intended function. Examples of the consequences of incorrect assembly include the following:

(1) an out-of-phase action, or

(2) reversal in the sense of the control, or

(3) interconnection of the controls between two systems where this is not intended, or

(4) loss of function.

b. Adequate precaution should be taken in the design process and adequate procedures should be specified in the maintenance manual to prevent the incorrect installation, connection, or adjustment of parts of the flight control system.

9. EVALUATION OF CONTROL SYSTEM FAILURES – 25.671(c).

The guidance provided in this advisory material for 25.671(c) is not intended to address requirement errors, design errors, software errors, or implementation errors. These are typically managed through development processes or system architecture, and are adequately addressed by SAE ARP 4754, DO-178B, and AC/AMJ 25.1309.

FAR/JAR 25.671(c) requires that the airplane be shown by analysis, tests, or both, to be capable of continued safe flight and landing following failures in the flight control system and surfaces (including trim, lift, drag, and feel systems) within the normal flight envelope, without requiring exceptional piloting skill or strength.

Subparagraph (c)(1) requires the evaluation of any single failure, excluding the types of jams addressed in subparagraph (c)(3). Subparagraph (c)(1) requires that any single failure be considered, suggesting that an alternative means of controlling the airplane or an alternative load path be provided in the case of a single failure. All single failures must be considered, even if they can be shown to be extremely improbable. The single failure considerations of AC/AMJ 25.1309 apply.

Subparagraph (c)(2) requires the evaluation of any combination of failures, excluding the types of jams addressed in subparagraph (c)(3), not shown to be extremely improbable. For this application, extremely improbable is defined based on the criteria established in AC/AMJ 25.1309. In addition, subparagraph (c)(2) states that after any single failure in the flight control system, additional failure states that could prevent continued safe flight and landing shall have a combined probability of less than 1 in 1000. A probability of less than 1 in 1000 is not a failure rate but a time based probabilistic parameter intended to provide a required minimum residual airplane capability following a single flight control system failure.

Subparagraph (c)(3) requires the evaluation of any failure or event that results in a jam of a flight control surface or pilot control. This subparagraph is intended to address failure modes that would result in the surface or pilot's control being fixed at the position commanded at the time of the failure due to some physical interference. The position at the time of the jam should be at any normally encountered control position encountered during takeoff, climb, cruise, normal turns, descent, and landing. In some architectures, component jams within the system may result in

failure modes other than a fixed surface or pilot control; those types of jams are considered under subparagraphs (c)(1), (c)(2), and (c)(4).

In the past, determining a consistent and reasonable definition of normally encountered control positions has been difficult. A review of in-service fleet experience, to date, showed that the overall failure rate for a control surface jam is approximately 10^{-6} to 10^{-7} per flight hour. Considering this in-service data, a reasonable definition of normally encountered positions represents the range of control surface deflections (from neutral to the largest deflection) expected to occur in 1000 random operational flights, without considering other failures, for each of the flight segments identified in the rule.

One method of establishing acceptable control surface deflections is the performance-based criteria outlined in this AC which were established to eliminate any differences between aircraft types. The performance-based criteria prescribe environmental and operational maneuver conditions, and the resulting deflections may be considered normally encountered positions for compliance with FAR/JAR 25.671(c)(3).

Alleviation means may be used to show compliance with subparagraph (c)(3). For this purpose, alleviation means include system reconfigurations, jam prevention design features, or any other features that eliminate or reduce the consequences of a jam or permit continued safe flight and landing.

Subparagraph (c)(3) also states that in the presence of a jam that results in a fixed position of a flight control surface or pilot control, additional failure conditions that could prevent continued safe flight and landing shall have a combined probability of less than 1 in 1000 of existing. As with subparagraph (c)(2), a probability of less than 1 in 1000 is not a failure rate but a time based probabilistic parameter intend to provide a required minimum residual airplane capability following this type of jam.

Subparagraph (c)(4) requires that any runaway of a flight control to an adverse position be accounted for if such a runaway is due to a single failure or due to a combination of failures not shown to be extremely improbable. Means to alleviate the runaway may be used to show compliance by reconfiguring the control system, deactivating the system (or a failed portion thereof), overriding the runaway by movement of the flight controls in the normal sense, eliminating the consequences of a runaway in order to ensure continued safe flight and landing following a runaway, or using a means of preventing a runaway. Without a suitable means to alleviate or prevent the runaway, an adverse position would represent any position for which they are approved to operate.

All approved aircraft gross weights and cg locations should be considered. However, only critical combinations of gross weight and cg need to be demonstrated.

ENCLOSURE 2

a. Compliance with FAR/JAR 25.671(c)(2). In showing compliance with the multiple failure requirements of FAR/JAR 25.671(c)(2), two different types of analysis/assessment are necessary.

(1) The first analysis/assessment requires that the airplane be capable of continued safe flight and landing following any combination of failures not shown to be extremely improbable. To satisfy this initial requirement, a safety analysis according to the techniques of AC/AMJ 25.1309 should be used.

(2) To comply with the second part of FAR/JAR 25.671(c)(2), the applicant is required to show that in the presence of any single failure in the flight control system (regardless of probability), any additional failure state (subsequent or pre-existing) that could prevent continued safe flight and landing when combined with the single failure must have a probability of less than 1 in 1000 of existing. This additional requirement ensures that a minimum level of safety exists should the single failure occur. As such, it establishes a minimum required reliability for systems that provide a backup function to a primary system even though the primary system may have a very low failure probability (e.g., a 10^{-1} backup system to a 10^{-8} primary system would not be allowed).

Jams of the type addressed in (c)(3) are excluded from consideration under FAR/JAR 25.671(c)(2).

Given the current state of technology, some failure combinations such as dual electrical system or dual hydraulic system losses are not generally accepted as being extremely improbable.

The following is a general outline of the steps to perform the additional analysis for FAR/JAR 25.671(c)(2), following the safety analysis per AC/AMJ 25.1309:

(i) Systematically work through the flight control system and impose a single failure on each single component or element of the flight control system. The single failure is assumed to have happened, regardless of its calculated failure rate or probability.

(ii) With each single failure, identify any additional failure state(s) that would preclude continued safe flight and landing.

(iii) Accounting for dormancy period (check/inspection interval), exposure time, or at risk time, calculate the risk probability of encountering the additional failure state(s) that would preclude continued safe flight and landing. The risk probability of encountering any of these additional failure states(s) on the same flight as the single failure shall be less than 1 in 1000.

(iv) Repeat the above steps for each single failure in the flight control system.

Or viewed in another way, in showing compliance with the additional analysis of FAR/JAR 25.671(c)(2), for every numerical analysis that demonstrates a flight control failure condition that prevents continued safe flight and landing is extremely improbable, it shall be possible to substitute a probability of 1.0 at any individual gate or condition that represents a single failure, and the fault tree result due to the remainder of the analysis shall not be greater than 1 in 1000.

Appendix 2 gives simplified examples explaining how the 1 in 1000 analysis might be applied.

b. Determination of Control System Jam Positions – FAR/JAR 25.671(c)(3). The flight phases required by FAR/JAR 25.671 can be encompassed by three flight phases: takeoff, in-flight (climb, cruise, normal turns, descent, and approach), and landing. Takeoff is considered to be the time period between brake release and 35 ft. In-flight is considered to be from 35 ft following a takeoff to 50 ft prior to landing including climb, cruise, normal turns, descent, and approach.

25.671(c)(3) requires that the airplane be capable of landing with a flight control jam and that the airplane be evaluated for jams in the landing configuration. However, for the evaluation of jams which occur just prior to landing, proximity to the ground need not be considered for the transient condition. Given that some amount of time and altitude is necessary in order to recover from any significant flight control jam, there is no practical means by which such a recovery could be demonstrated all the way to touchdown. The potential delay in accomplishing a recovery could be on the order of 5 seconds as described in section 9.e. For a jam at a control deflection corresponding to .8 g, a recovery may not be possible below approximately 200' even with a state of the art control system. While it is recognized that this means that a specific hazard is not addressed(a control jam that occurs, or is recognized, just before landing), this hazard is mitigated for the following reasons. First, the landing phase represents a limited exposure window in which a jam could occur. Second, successful operation of the controls throughout the flight minimizes the likelihood of a jam suddenly appearing during the landing phase. Also, some sources of jamming such as icing are not prevalent in the landing phase. Third, a certain level of recovery capability will be ensured through compliance with this AC such that if a jam does occur during landing, the crew will have a reasonable chance of landing safely.

Only the airplane rigid body modes need to be considered when evaluating the aircraft response to maneuvers and continued safe flight to landing.

It is assumed that if the jam is detected prior to V_1, the takeoff will be rejected.

Although 1 in 1000 operational takeoffs is expected to include crosswinds up to 25 knots, the short exposure time associated with a control surface jam occurring between V_1 and V_{LOF} allows usage of a less conservative crosswind magnitude when determining normally encountered lateral and directional control positions. Given that lateral and directional controls are continuously used to maintain runway centerline in a crosswind takeoff, and control inputs greater than that necessary at V_1 will occur at speeds below V_1, any jam in these control axes during a crosswind takeoff will normally be detected prior to V_1. Considering the control jam failure rate of approximately 10^{-6} to 10^{-7} per flight hour combined with the short exposure time between V_1 and V_{LOF}, a reasonable crosswind level for determination of jammed lateral or directional control positions during takeoff is 15 knots.

ENCLOSURE 2

The jam positions to be considered in showing compliance include any position up to the maximum position determined by the following maneuvers. The maneuvers and conditions described in this section are only to provide the control surface deflection to evaluate continued safe flight and landing capability, and are not to represent flight test maneuvers for such an evaluation; see section 9.e."

(1) Jammed Lateral Control Positions.

(i) Takeoff: The lateral control position for wings-level at V1 in a steady crosswind of ~~the lesser of 25~~15 knots (at a height of 10 meters above the takeoff surface)~~ or the maximum demonstrated crosswind~~. Variations in wind speed from a 10 meter height can be obtained using the following relationship:

$$V_{alt} = V_{10meters} * (H_{desired}/10.0)^{1/7}$$

Where: $V_{10meters}$= Wind Speed at 10 meters AGL (knots)
V_{alt} = Wind Speed at desired altitude (knots)
$H_{desired}$ = Desired altitude for which Wind Speed is Sought

(Meters AGL), but not lower than 1.5m (5 ft)

(ii) In-flight: The lateral control position to sustain a 12 deg/sec steady roll rate from $1.23V_{SR1}(1.3V_S)$ to VMO/MMO or V_{fe}, as appropriate, but not greater than 50% of the control input.

Note: If the flight control system augments the pilot's input, then the maximum surface deflection to achieve the above maneuvers should be considered.

(2) Jammed Longitudinal Control Positions.

(i) Takeoff: Three longitudinal control positions should be considered:

(1) Any control position from that which the controls naturally assume without pilot input at the start of the takeoff roll to that which occurs at V1 using the manufacturer's recommended procedures.

Note: It may not be necessary to consider this case if it can be demonstrated that the pilot is aware of the jam before reaching V_1 (for example, through a manufacturer's recommended AFM procedure).

(2) The longitudinal control position at V_1 based on the manufacturers recommended procedures including consideration for any runway condition for which the aircraft is approved to operate.

(3) Using the manufacturers recommended procedures, the peak longitudinal control position to achieve a steady aircraft pitch rate of the lesser of 5 deg/sec or the pitch rate necessary to achieve the speed used for all-engines-operating initial climb procedures (V_2+XX) at 35 ft.

(ii) In-flight: The maximum longitudinal control position is the greater of :

(1) The longitudinal control position required to achieve steady state normal accelerations from 0.8g to 1.3g at speeds from $1.23V_{SR1}$($1.3V_S$) to V_{MO}/M_{MO} or V_{fe}, as appropriate.

(2) The peak longitudinal control position commanded by the stability augmentation or other automatic system in response to atmospheric discrete vertical gust defined by 15 fps from sea level to 20,000 ft.

(3) Jammed Directional Control Positions.

(i) Takeoff: The directional control position for takeoff at V1 in a steady crosswind of ~~to the lesser of 25~~15 knots (at a height of 10 meters above the takeoff surface)~~ or the maximum demonstrated crosswind~~. Variations in wind speed from a height of 10 meters can be obtained using the following relationship:

$$V_{alt} = V_{10meters} * (H_{desired}/10.0)^{1/7}$$

Where: $V_{10meters}$ = Wind Speed at 10 meters AGL (knots)
V_{alt} = Wind Speed at desired altitude (knots)
$H_{desired}$ = Desired altitude for which Wind Speed is Sought

(Meters AGL), but not lower than 1.5m (5 ft)

(ii) In-flight: The directional control position is the greater of:

(1) The peak directional control position commanded by the stability augmentation or other automatic system in response to atmospheric discrete lateral gust defined by 15 fps from sea level to 20,000 ft.

(2) Maximum rudder angle required for lateral/directional trim from $1.23V_{SR1}(1.3V_S)$ to the maximum all engines operating airspeed in level flight with climb power, but not to exceed V_{MO}/M_{MO} or V_{fe} as appropriate. While more commonly a characteristic of propeller aircraft, this addresses any lateral/directional asymmetry that can occur in flight with symmetric power.

(4) Control Tabs, Trim Tabs, and Trimming Stabilizers. Any tabs installed on control surfaces are assumed jammed in the position associated with the normal deflection of the control surface on which they are installed.

Trim tabs and trimming stabilizers are assumed jammed in the positions associated with the manufacturer's recommended procedures for takeoff and that are normally used throughout the flight to trim the aircraft from $1.23V_{SR1}(1.3V_S)$ to V_{MO}/M_{MO} or V_{fe}, as appropriate.

(5) Speed Brakes. Speed brakes are assumed jammed in any position for which they are approved to operate during flight at any speed from $1.23V_{SR1}(1.3V_S)$ to V_{MO}/M_{MO} or V_{fe}, as appropriate. Asymmetric extension and retraction of the speed brakes should be considered. Roll spoiler jamming (asymmetric spoiler panel) is addressed in Section 9.b.1.

(6) High Lift Devices. Leading edge and trailing edge high lift devices are assumed to jam in any position for takeoff, climb, cruise, approach, and landing. Skew of high lift devices or asymmetric extension and retraction should be considered; FAR/JAR 25.701 contains a requirement for flap mechanical interconnection unless the aircraft has safe flight characteristics with the asymmetric flap positions not shown to be extremely improbable.

(7) Load Alleviation Systems.

(i) Gust Load Alleviation Systems. At any airspeed between $1.23V_{SR1}(1.3V_S)$ to V_{MO}/M_{MO} or V_{fe}, as appropriate, the control surfaces are assumed to jam in the maximum position commanded by the gust load alleviation system in response to a discrete atmospheric gust with the following reference velocities:

(1) 15 fps (EAS) from sea level to 20,000 ft (vertical gust),

(2) 15 fps (EAS) from sea level to 20,000 ft (lateral gust).

(ii) Maneuver Load Alleviation Systems. At any airspeed between $1.23V_{Sr1}(1.3V_{Smin})/V_{ref}$ to $V_{MO}/M_{MO}/V_{fe}$ the control surfaces are assumed to jam in the maximum position commanded by the maneuver load alleviation system during a pull-up maneuver to 1.3g or a pushover maneuver to 0.8g.

c. Jam Combination Failures – FAR/JAR 25.671(c)(3). In addition to demonstration of jams at "normally encountered position," compliance with FAR/JAR 25.671(c)(3) should include an analysis that shows a minimum level of safety exists should the jam occur. This additional analysis should show that in the presence of a jam considered under 25.671(c)(3), any additional failure state that could prevent continued safe flight and landing when combined with the jam must have a probability of less than 1 in 1000 of existing. (This analysis uses the same methods for demonstration of compliance with 25.671(c)(2), where the jam is the single failure.) As a minimum, this should include analysis of such elements as a jam breakout or override, disconnect means, alternate surface control, alternate electrical or hydraulic sources, or alternate cable paths. This analysis should help determine intervals for scheduled maintenance activity or operational checks that ensure the availability of alleviation or compensation means.

d. Runaway to an Adverse Position – FAR/JAR 25.671(c)(4). Consideration of a control runaway will be specific to each application and a general interpretation of an adverse position cannot be given. Where applicable, the applicant is required to assess the resulting surface position after a runaway, if the failure condition is not extremely improbable or can occur due to a single failure. This applies to all controls discussed in Section 9.b.

e. Assessment of Continued Safe Flight and Landing – FAR/JAR 25.671(c). Following a flight control system failure of the types discussed in Sections 9.a, 9.b, 9.c, and 9.d, the maneuverability and structural strength criteria defined in the following sections should be considered to determine the airplane's capability for continued safe flight and landing.

(1) Flight Characteristics.

(i) General. Following control system failure, appropriate procedures may be used including system reconfiguration, flight limitations, and crew resource management. The procedures for safe flight and landing should not require exceptional piloting skill or strength.

Additional means of control, such as trim system, may be used if it can be shown that the systems are available and effective. Credit should not be given for use of differential engine thrust to maneuver the aircraft. However, differential thrust may be used following the recovery to maintain lateral/directional trim following the flight control system failure.

For the longitudinal control surface jam during takeoff prior to rotation, it is necessary to show that the aircraft can be safely rotated for liftoff without consideration of field length available.

(ii) Transient Response. There should be no unsafe conditions during the transient condition following a flight control system failure. The evaluation of failures, or maneuvers leading to jamming, is intended to be initiated at 1g wings-level flight. For this purpose, continued safe flight and landing is generally defined as not exceeding any one of the following:

(1) A load on any part of the primary structure sufficient to cause a catastrophic structural failure

(2) Catastrophic loss of flight path control

(3) Exceedance of Vdf/Mdf

(4) Catastrophic Flutter or vibration

(5) Bank angle in excess of 90 degrees

In connection with the transient response, compliance should be shown to the requirements of FAR/JAR 25.302. While V_F is normally an appropriate airspeed limit to be considered regarding continued safe flight and landing, temporary exceedence of V_F may be acceptable as long as the requirements of FAR/JAR 25.302 are met.

ENCLOSURE 2

Paragraph 9.b. provides a means of determining control surface deflections for the evaluation of flight control jams. In some cases, aircraft roll or pitch rate or normal acceleration is used as a basis to determine these deflections. The roll or pitch rate and/or normal acceleration used to determine the control surface deflection need not be included in the evaluation of the transient condition. For example, the in-flight lateral control position determined in paragraph 9.b.(1)(ii) is based on a steady roll rate of 12 degrees per second. When evaluating this condition, whether by analysis, simulation or in-flight demonstration, the resulting control surface deflection is simply input while the airplane is in wings-level flight, at the appropriate speed, altitude, etc. During this evaluation, the airplane's actual roll or pitch rate may or may not be the same as the roll or pitch rate used to determine the jammed control surface position

(iii) Delay Times. Due consideration should be given to the delays involved in pilot recognition, reaction, and operation of any disconnect systems, if applicable.

Delay = Recognition + Reaction + Operation of Disconnect

Recognition is defined as the time from the failure condition to the point at which a pilot in service operation may be expected to recognize the need to take action. Recognition of the malfunction may be through the behavior of the airplane or a reliable failure warning system, and the recognition point should be identified but should not normally be less than 1 second. For flight control system failures, except the type of jams addressed in (c)(3), control column or wheel movements alone should not be used for recognition.

The following reaction times should be used:

Flight Condition	Reaction Time
On Ground	1 sec (**)
In Air, (<1000 ft AGL)	1 sec (**)
Manual Flight (>1000 ft AGL)	1 sec (**)
Automatic Flight (>1000 ft AGL)	3 sec

(**) 3 sec if control must be transferred between pilots.

The time required to operate any disconnect system should be measured either through ground tests or during flight testing. This value should be used during all analysis efforts. However, flight testing or manned simulation that requires the pilot to operate the disconnect includes this extra time; therefore, no additional delay time would be needed for these demonstrations.

(iv) Maneuver Capability for Continued Safe Flight and Landing. If, using the manufacturer's recommended procedures, the following maneuvers can be performed following the failure, it will generally be considered that continued safe flight and landing has been shown.

(1) A steady 30° banked turn to the left or right,

(2) A roll from a steady 30° banked turn through an angle of 60° so as to reverse the direction of the turn in not more than 11 seconds (in this maneuver the rudder may be used to the extent necessary to minimize sideslip, and the maneuver may be unchecked),

(3) A pushover maneuver to 0.8g, and a pull-up maneuver to 1.3g,

(4) A wings level landing flare in a 90° crosswind of up to 10 knots (measured at 10 meters above the ground).

Note: For the case of a lateral or directional control system jam during takeoff that is described in Section 9(b)(1) or 9(b)(3), it should be shown that the aircraft can safely land on a suitable runway with any crosswind from 0 kt to the crosswind level and direction at which the jam was established.

~~**Note:** For the case of control surface jams during takeoff that are detected by the flight crew, it may be assumed that the aircraft is returned to a suitable runway, including consideration of crosswind. As a result, it can be assumed that the aircraft is returned to a runway with a favorable crosswind no more than 15 knots less than the crosswind at the time of the jam.~~

(v) Control Forces. The short and long term control forces should not be greater than 1.5 times the short and long term control forces allowed by FAR/JAR 25.143(c).

Short term forces have typically been interpreted to mean the time required to accomplish a configuration or trim change. However, taking into account the capability of the crew to share the workload, the short term forces of 25.143(c) may be appropriate for a longer duration, such as the evaluation of a jam on takeoff and return to landing.

During the recovery following the failure, transient control forces may exceed these criteria to a limited extent. Acceptability of any exceedances will be evaluated on a case by case basis.

(2) Structural Strength for Flight Control System Failures.

(i) Failure Conditions per FAR/JAR 25.671(c)(1), (c)(2), and (c)(4). It should be shown that the aircraft maintains structural integrity for continued safe flight and landing. This should be accomplished by showing compliance with FAR/JAR 25.302 (Interaction with Systems and Structures). In FAR/JAR 25.302, a failure is declared extremely improbable based solely on a quantitative probability. However, some failures may exhibit failure rates that are less than 10^{-9} per flight hour and not be classified as extremely improbable (some single failures may fall into this category). The level of structural strength assessment should be according to the probability of the failure as defined below:

Failure Probability (Quantitative Assessment)	Failure Probability (Qualitative Assessment)	Structural Substantiation
$>10^{-9}$ per flight hour	Not Extremely Improbable	As per FAR/JAR 25.302, Appendix K25.1(c)
$<10^{-9}$ per flight hour	Not Extremely Improbable	As per Section 9.e.2.iii
$<10^{-9}$ per flight hour	Extremely Improbable	None

(ii) Jam Conditions per FAR/JAR 25.671(c)(3). It should be shown that the aircraft maintains structural integrity for continued safe flight and landing. Recognizing that jams are infrequent occurrences and that margins have been taken in the definition of normally encountered positions of this Advisory Circular, criteria other than those specified in FAR/JAR 25.302 Appendix K25.1(c) may be used for structural substantiation to show continued safe flight and landing.

This structural substantiation should be per Section 9.e.2.iii

(iii) Structural Substantiation. The loads considered as ultimate should be derived from the following conditions at speeds up to the maximum speed allowed for the jammed position or for the failure condition:

(1) Balanced maneuver of the airplane between 0.25g and 1.75g with high lift devices fully retracted and in enroute configurations, and between 0.6g and 1.4g with high lift devices extended,

(2) Vertical and lateral discrete gusts corresponding to 40% of the limit gust velocity specified at Vc in FAR/JAR 25.341(a) with high lift devices fully retracted, and a 17 fps vertical and 17 fps head-on gust with high lift devices extended.

ENCLOSURE 2

10. EVALUATION OF ALL-ENGINES FAILED CONDITION – 25.671(d).

a. Explanation. FAR/JAR 25.671(d) states that, "The airplane must be designed so that it is controllable and an approach and flare to a landing possible if all engines fail at any point in the flight. Compliance with the requirement may be shown by analysis where that method has been shown to be reliable."

The intent of FAR/JAR 25.671(d) is to assure that in the event of failure of all engines and given the availability of an adequate runway, the airplane will be controllable and an approach and flare to a landing possible. In this context, "flare to a landing" refers to the time until touchdown. Although the rule refers to "flare to a landing" with the implication of being on a runway, it is recognized that with all engines inoperative it may not be possible to reach an adequate runway or landing surface; in this case the aircraft must still be able to make a flare to landing attitude.

FAR/JAR 25.671(d) effectively requires airplanes with fully powered or electronic flight control systems to have a source for emergency power, such as an air driven generator, wind-milling engines, batteries, or other power source capable of providing adequate power to the flight control system.

Analysis, simulation, or any combination thereof may be used to show compliance where the methods are shown to be reliable.

b. Procedures.

(1) The airplane should be evaluated to determine that it is possible, without requiring exceptional piloting skill or strength, to maintain control following the failure of all engines, including the time it takes for activating any backup systems. The airplane should also remain controllable during restart of the most critical engine, whilst following the AFM recommended engine restart procedures.

(2) The most critical flight phases, especially for airplanes with emergency power systems dependent on airspeed, are likely to be takeoff and landing. Credit may be taken for hydraulic pressure/electrical power produced while the engines are spinning down and any residual hydraulic pressure remaining in the system. Sufficient power must be available to complete a wings level approach and flare to a landing.

Analyses or tests may be used to demonstrate the capability of the control systems to maintain adequate hydraulic pressure/electrical power during the time between the failure of the engines and the activation of any backup systems. If any of the

backup systems rely on aerodynamic means to generate power, then a flight test demonstration should be performed to demonstrate that the backup system could supply adequate electrical and hydraulic power to the flight control systems. The flight test should be conducted at the minimum practical airspeed required to perform an approach and flare to a safe landing attitude.

(3) The maneuver capability following the failure of all engines should be sufficient to complete an approach and flare to a landing. Note that the aircraft weight could be extremely low (e.g., the engine failures could be due to fuel exhaustion). The maximum speeds for approach and landing may be limited by other Part 25 requirements (e.g., ditching, tire speeds, flap or landing gear speeds, etc.) or by an evaluation of the average pilot's ability to conduct a safe landing. At an operational weight determined for this case and for any other critical weights and c.g.'s identified by the applicant, at speeds down to the approach speeds appropriate to the aircraft configuration, the aircraft should be capable of:

(i) A steady 30° banked turn to the left or right,

(ii) A roll from a steady 30° banked turn through an angle of 60° so as to reverse the direction of the turn in not more than 11 seconds (in this maneuver the rudder may be used to the extent necessary to minimize sideslip, and the maneuver may be unchecked),

(iii) A pushover maneuver to 0.8g, and a pull-up maneuver to 1.3g,

(iv) A wings level landing flare in a 90° crosswind of up to 10 knots (measured at 10 meters above the ground).

Note: If the loss of all engines has no effect on the control authority of the aircraft (e.g., manual controls) then the results of the basic handling qualities flight tests with all engines operating may be used to demonstrate the satisfactory handling qualities of the airplane with all engines failed.

(4) It should be possible to perform a flare to a safe landing attitude, in the most critical configuration, from a stabilized approach using the recommended approach speeds and the appropriate AFM procedures, without requiring exceptional piloting skill or strength. For transient maneuvers, forces are allowed up to 1.5 times those specified in FAR/JAR 25.143(c) for temporary application with two hands available for control.

ENCLOSURE 2

11. EVALUATION OF CONTROL AUTHORITY AWARENESS – 25.671(e).

a. FAR/JAR 25.671(e) requires suitable annunciation to be provided to the flight crew when a flight condition exists in which near-full control authority (not pilot-commanded) is being used. Suitability of such a display must take into account that some pilot-demanded maneuvers (e.g., rapid roll) are necessarily associated with intended full performance, which may saturate the surface. Therefore, simple alerting systems, which would function in both intended and unexpected control-limiting situations, must be properly balanced between needed crew-awareness and nuisance alerting. Nuisance alerting should be minimized. The term suitable indicates an appropriate balance between nuisance and necessary operation.

b. Depending on the application, suitable annunciations may include cockpit control position, annunciator light, or surface position indicators. Furthermore, this requirement applies at limits of control authority, not necessarily at limits of any individual surface travel.

12. EVALUATION OF FLIGHT CONTROL SYSTEM SUBMODES – 25.671(f).

Some systems, EFCS in particular, may have submodes of operation not restricted to being either on or off. The means provided to the crew to indicate the current submode of operation may be different from the classic "failure warning."

ENCLOSURE 2

13. ACCEPTABLE MEANS OF COMPLIANCE DEMONSTRATION.

It is recognized that it may be neither practical nor appropriate to demonstrate compliance by flight test for all of the failure conditions noted herein. Compliance may be shown by analysis, simulation, a piloted engineering simulator, flight test, or combination of these methods as agreed with the certification authority. Simulation methods should include an accurate representation of the aircraft characteristics and of the pilot response, including time delays as specified in Section 9.e.1.iii.

Efforts to show compliance with this regulation may result in flight manual abnormal procedures. Verification of these procedures may be accomplished in-flight or, with the agreement of the certification authority, using a piloted simulator.

a. Acceptable Use of Simulations. It is generally difficult to define the types of simulations that might be acceptable in lieu of flight testing without identifying specific conditions or issues. However, the following general principles can be used as guidance for making this kind of decision:

   (1) In general, flight test demonstrations are the preferred method to show compliance.

   (2) Simulation may be an acceptable alternative to flight demonstrations, especially when:

      (i) A flight demonstration would be too risky even after attempts to mitigate these risks (e.g., "simulated" takeoffs/landings at high altitude),

      (ii) The required environmental conditions are too difficult to attain (e.g., windshear, high crosswinds),

      (iii) The simulation is used to augment a reasonably broad flight test program,

      (iv) The simulation is used to demonstrate repeatability.

b. Simulation Requirements. Where it is agreed that a simulation will be used to establish compliance, to be acceptable for use in showing compliance with the performance and handling qualities requirements the simulation should:

   (1) Be suitably validated by flight test data for the conditions of interest.

(i) This does not mean that there must be flight test data at the exact conditions of interest; the reason simulation is being used may be that it is too difficult or risky to obtain flight test data at the conditions of interest.

(ii) The level of substantiation of the simulator to flight correlation should be commensurate with the level of compliance (i.e., unless it is determined that the simulation is conservative, the closer the case is to being non-compliant, the higher the required quality of the simulation).

(2) Be conducted in a manner appropriate to the case and conditions of interest.

(i) If closed-loop responses are important, the simulation should be piloted by a human pilot.

(ii) For piloted simulations, the controls/displays/cues should be substantially equivalent to what would be available in the real airplane (unless it is determined that not doing so would provide added conservatism).

ENCLOSURE 2

APPENDIX 1. FAILURE RATE AND PROBABILITY CONSIDERATIONS.

a. Failure Rates.

An important aspect in performing the analyses to show compliance with both multiple failure requirements of FAR/JAR 25.671(c)(2) is the determination of failure rates. The failure rates are used in the fault tree analysis per FAR/JAR 25.1309 to determine the overall probability of failure combinations to ensure the probability is commensurate with the failure effects. Failure rates are also used to calculate the probability (i.e., risk) of additional failures, or of being in a failed state, that may preclude continued safe flight and landing following the single failure.

Failure rates should be conservative and adequately substantiated to yield an acceptable level of confidence. In order of preference, the following sources should be considered for calculating conservative/substantiated failure rates: manufacturer/vendor in-service data of like or similar components used in a similar application and similar environment, vendor prediction, industry standard (i.e., NPRD data), and engineering judgement based on prior experience with similar components. The methods of obtaining failure rates should be explained and traceability to sources should be maintained. Built-in conservatism in the analysis should also be explained. The certification agencies have the opportunity to question or discuss any failure rates in the course of reviewing safety analysis materials. Following certification, the manufacturer should monitor for in-service deviations from safety analysis assumed failure rates.

In some cases, manufacturers use published company design standards as one means to promote consistency and improvement of component failure rates. These standards typically specify environments, design features, and other considerations that the manufacturer's past design and service experience has shown provides acceptable service reliability. Generally, future components that adhere to these standards are expected to achieve reliabilities similar to predecessor components. .

To aid in providing confidence in the analysis, sensitivity analyses should be conducted on the failure rates used in the fault tree analysis for 25.1309 to show the top failure condition probability still allows compliance to be shown.

b. Failure Rate vs. Probability.

In the analysis required by the second sentence of FAR/JAR 25.671(c)(2), it is important to note that the "probability of less than 1 in 1000" for the additional failure state(s) that would preclude continued safe flight and landing is not to be confused with a failure rate of 10^{-3} per flight hour. Failure rates are expressed in "per flight hour" or "per flight" terms. The "probability" in the requirement is unitless and represents the "risk" of

encountering those additional failure(s) during the same flight. For example, after the failure of the primary system, a backup system that is monitored with a failure rate of $1x10^{-5}$ per flight hour (active failure) would have a probability of encountering that additional failure during the same flight of $1x10^{-5}$ for a 1 hour flight, $3x10^{-5}$ for a 3 hour flight, and $1x10^{-4}$ for a 10 hour flight.

Dormancy periods also factor into the calculation of the 1 in 1000 probability. In the example of the $1x10^{-5}$/FH backup system, if this were a dormant failure, then a check for the presence of the dormant failure must be performed every 100 hours to comply with the 1 in 1000 probability.

The above examples assume that the airplane is "at risk" of the additional failure for the duration of the flight. For cases where the airplane is at risk of the additional failure only during a limited portion of the flight, at risk time is used to determine the risk probability.

Flight time, dormancy period, exposure time, and at risk time all combine to contribute to the risk probability of the additional failures.

APPENDIX 2. EXAMPLES OF 25.671(c)(2)'s 1 in 1000 REQUIREMENT.

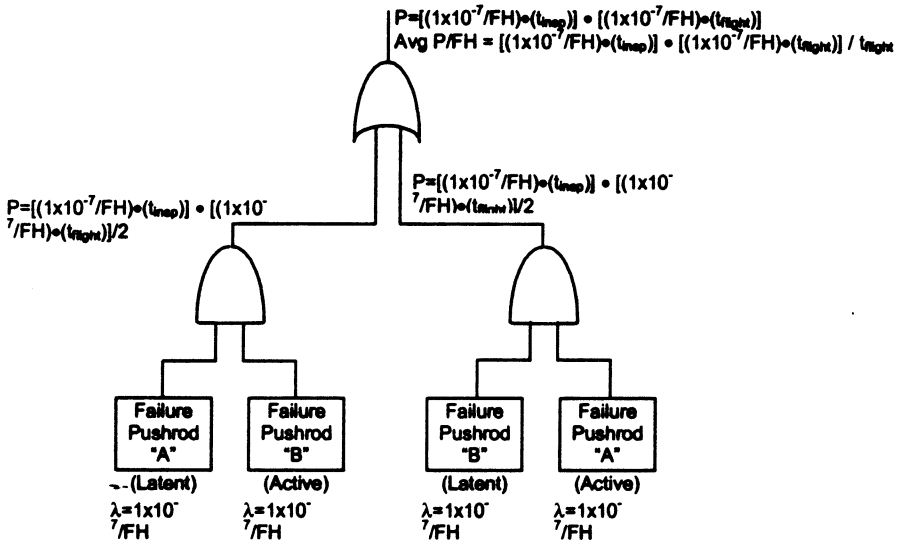
The following simplified examples explain how the additional 1 in 1000 requirement in FAR/JAR 25.671(c)(2) might be applied. Since many other factors influence the acceptability and certificability of a design, inclusion of a design as an example does not imply the design will always be acceptable; the examples below are only included to illustrate the additional investigation required under FAR/JAR 25.671(c)(2).

a. Example #1 – Dual Load-Path.

Although there are other requirements that govern such a design, consider a simplified case of a dual load-path design where two pushrods connect actuators to an unbalanced surface. Assume that a free-floating surface could preclude continued safe flight and landing in any flight phase and therefore must be guarded against.

For this example each pushrod is designed to carry the full load in the absence of the other, the pushrods are independent of one another, and they are readily inspectable. However, since the failure of one pushrod (one load-path) would not be readily apparent to the crew, that failure would be dormant.

(1) FAR/JAR 25.1309 Considerations -- Suppose the manufacturer has sufficient service history data to justify a failure of a pushrod is $1x10^{-7}$/FH. Under a strict FAR/JAR 25.1309 approach and taking into account the dormancy of the failure, the failure of both pushrods in combination has a probability of occurrence per flight hour of...



{ [(1x10^{-7}/FH Pushrod Failure) • (t_{insp} hr dormancy period)] •

[(1x10^{-7}/FH Pushrod Failure) • (t_{flight} hr avg flight)] } / (t_{flight} hr avg flight)

< 1x10^{-9}/FH

Since the "t_{flight} avg flight" term cancels out of the equation, solving for the maximum acceptable dormancy period that still satisfies the 1x10^{-9}/FH criteria yields a dormancy period (i.e., inspection interval) of 100,000 FH.

(2) FAR/JAR 25.671(c)(2) Considerations -- Now look at the additional multiple failure requirement in the second sentence of FAR/JAR 25.671(c)(2). The single failure is assumed to have occurred, regardless of probability; in this example the failure of one pushrod is the single failure. The additional failure that could preclude continued safe flight and landing is identified as the failure of the other pushrod. Now look to see if the probability of encountering the additional failure is less than 1 in 1000.

Since the additional failure is dormant, to calculate the probability that the additional failure has already occurred (or will occur) the full dormancy period is applied first using the inspection interval established for compliance with FAR/JAR 25.1309.

(1x10^{-7}/FH Pushrod Failure) • (100,000 hr check) = 4x10^{-2} (or 1 in 25)

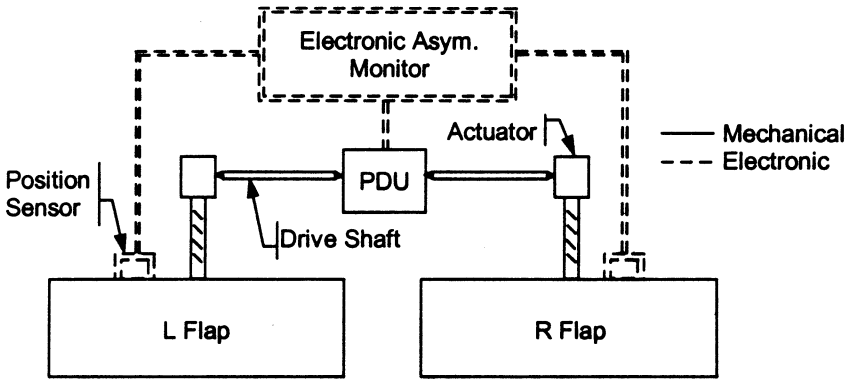
Since the inspection interval for compliance with FAR/JAR 25.1309 does not satisfy the 1 in 1000 criteria in the second part of FAR/JAR 25.671(c)(2), the inspection interval is recalculated to comply with the 1 in 1000 criteria.

(1x10^{-7}/FH Pushrod Failure) • (t_{insp} hr dormancy period) < 1x10^{-3} (or 1 in 1000)

Solving for the inspection interval to satisfy 1 in 1000 yields an inspection interval (dormancy period) of no more than 10,000 hrs. In this case, the 1 in 1000 criteria in FAR/JAR 25.671(c)(2) would be more restrictive than 25.1309.

b. Example #2 – Flap System and Asymmetry Detection.

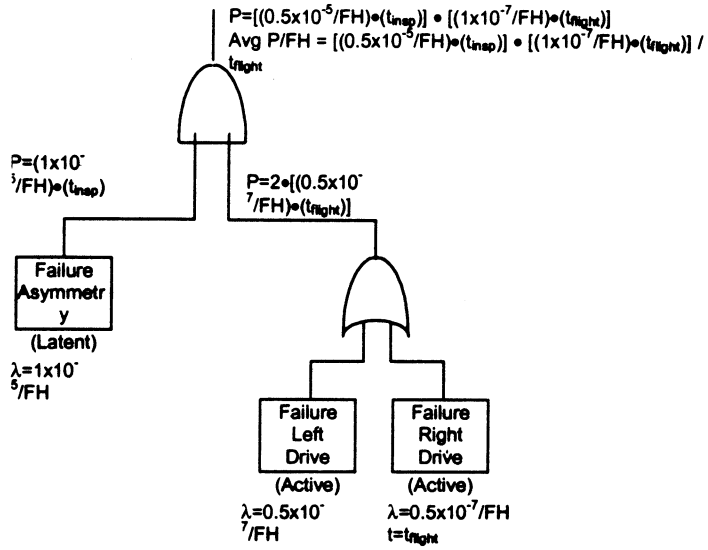
Although there are other requirements that govern such a design, consider the simplified flap drive system shown. Assume that excessive asymmetry could preclude continued safe flight and landing in any flight phase; therefore, excessive asymmetry must be sufficiently guarded against throughout the flight (i.e., at risk time could not be used in this case).



In this example a central power drive unit drives, through drive shafts, irreversible actuators at the flap surface. In the absence of the asymmetry monitor, a severance of the drive shaft just outside the PDU results in one flap being driven and the other flap remaining in its last commanded position – excessive asymmetry could develop. Since this excessive asymmetry is not extremely improbable, an electronic flap asymmetry monitor checks the position of each flap and shuts down the power drive unit should excessive asymmetry start to develop. The asymmetry monitor is passive; it only shuts down the PDU when it detects an excessive asymmetry.

(1) FAR/JAR 25.1309 Considerations -- Suppose the manufacturer has sufficient service history data to justify the probability of either drive shaft severance is approximately $1x10^{-7}$/FH. Under a strict FAR/JAR 25.1309 approach, to ensure that excessive flap asymmetry is extremely improbable the likelihood of either drive shaft severance combined with the likelihood of an asymmetry monitor failure would need to be less than $1x10^{-9}$/FH.

Suppose the manufacturer has sufficient service experience with similar electronic monitor systems to justify a failure rate (fail to inoperative status) of $1x10^{-5}$/FH. In the example, the failure of the monitor is dormant since the monitor takes no action until it detects the asymmetry; therefore, a periodic check is established to satisfy the required minimum reliability for 25.1309.



{ [($1x10^{-5}$/FH Monitor Failure) • (t_{insp} hr dormancy period)] •

[($0.5x10^{-7}$/FH Either Drive Shaft Severance) • (t_{flight} hr avg flight)] }

/ (t_{flight} hr avg flight) < $1x10^{-9}$/FH

Since the "t_{flight} avg flight" term cancels out of the equation, solving for the maximum acceptable dormancy period that still satisfies the $1x10^{-9}$/FH criteria yields a dormancy period (i.e., inspection interval) of 2,000 FH.

(2) FAR/JAR 25.671(c)(2) Considerations -- Now look at the additional multiple failure requirement in the second sentence of FAR/JAR 25.671(c)(2). The single failure is assumed to have occurred, regardless of probability. If the assumed single failure is the failure of the asymmetry monitor, the additional failure(s) that could preclude continued safe flight and landing is the failure of the drive shaft. Now look to see if the probability of encountering the additional failure(s) is less than 1 in 1000.

($1x10^{-7}$/FH Either Drive Shaft Sev.) • (t_{flight} hr avg flight) < $1x10^{-3}$ (or 1 in 1000)

Since the probability of encountering the drive shaft failure is on the order of 1 in 10,000,000 (depending on the duration of the average flight) compared to a 1 in 1000 requirement, compliance with the multiple failure requirements of FAR/JAR 25.671(c)(2) is shown for this single failure condition.

If the assumed single failure is the failure of the drive shaft, the additional failure(s) that could preclude continued safe flight and landing is the failure of the asymmetry monitor. Now look to see if the probability of encountering the additional failure(s) is less than 1 in 1000. Since the additional failure is dormant, the full dormancy period is applied first using the inspection interval established for compliance with FAR/JAR 25.1309.

($1x10^{-5}$/FH Monitor failure) • (2000 hr check) = $2x10^{-2}$ (or 1 in 50)

Since the 2000 hr inspection interval for compliance with FAR/JAR 25.1309 does not satisfy the 1 in 1000 criteria in the second part of FAR/JAR 25.671(c)(2), a design change would be necessary. Options available include: (1) change the monitor to self-check so it is no longer a dormant failure, (2) change to a redundant drive path or redundant monitor path, (3) improve the reliability of the monitor, or (4) reduce the check interval on the monitor. For this example, let's recalculate the inspection interval to comply with the 1 in 1000 criteria.

$(1x10^{-5}$/FH Monitor Failure) • (t_{insp} hr dormancy period) < $1x10^{-3}$ (or 1 in 1000)

Solving for the inspection interval to satisfy 1 in 1000 yields an inspection interval (dormancy period) of no more than 100 hrs. In this case, the 1 in 1000 criteria in FAR/JAR 25.671(c)(2) would be more restrictive than 25.1309.